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Realities in ossiculoplasty

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Abstract

The results of ossiculoplasty are frequently reported in terms of closure of the air-bone gap. This parameter is a reliable indicator of the degree of technical success, and is useful in comparing different materials and types of reconstructions. However, assessment of the operated ear alone does not evaluate the effect of surgery on binaural hearing ability, leading to the situation where sub-optimal advice may be given to patients pre-operatively. This article advocates a more patient orientated method of assessing the results of ossiculoplasty. Previous studies have indicated that the operated ear must reach an air conduction level of 30 dB for the speech frequencies, or be within 15 dB of the other ear, to ensure that the patient will gain significant benefit. A graphical method for the prediction of patient benefit is presented, and compared to the rule of thumb quoted above. The implications for surgeons and patients considering ossiculoplasty are obvious.

Many statements routinely made to patients prior to surgery for conductive hearing loss are unduly optimistic and unrelated to the realities of reported results. There is a need to determine what types of such hearing losses can be helped surgically, and more importantly to what extent the patients hearing disability can be relieved.

Introduction

Ojala (1979) who stated that hearing after tympanoplasty usually does not improve (and in some cases even deteriorates), and Fikentscher *et al.,* (1978) who stated that surgery was a means of preserving hearing, not improving it, both summed up the situation in the seventies. When we consider the numerous materials that have been employed in reconstruction tympanoplasty and the length of time since their introduction, it is very clear that factual information about their performance is long overdue.

Sadly, scant regard has been paid to this aspect of prognostication in chronic ear disease. Going back to first principles it is useful to review the prerequisites for success in tympanoplasty. Firstly, the tympanic membrane must be normally sited and mobile post-operatively. Secondly, there must be normal middle ear pressure and mucus clearance, and thirdly there must be an efficient sound conducting mechanism. Defects of the sound conducting mechanism range in order of frequency from a loss of the long process of the incus, to an absent incus and partially eroded crura, to ears where the only remaining ossicular remnant is the stapes footplate which may be immobile due to tympanosclerosis.

The commonest method of reconstructing these various defects utilizes homologous ossicular bone or cartilage to form a strut to restore the sound conducting mechanism. It is probable that the many failures of these reconstructions are due to a lack of understanding of the essentials of the sound transmission in the reconstructed ear. Vlaming and Feenstra (1986) have studied the phenomena in temporal bone preparations using a laser Doppler interferometer. Achievement of a piston-like movement of the stapes footplate proved to be the most effective in producing displacement of vestibular fluids. Ossicular reconstructions which produce tilting of the stapes induce markedly less movement of vestibular fluids. In general, transmission of lower frequency stimuli is more efficient than for the higher frequencies. In malleus-stapes assembly (MSA) reconstructions the position of the prosthesis is critical—the smaller the angle between the resolved components of the applied forces the greater the efficiency of transmission. However in columellar systems between the tympanic membrane or malleus and the footplate, the site of contact on the footplate is less critical to the magnitude of transmission, than the tension of the prosthesis. These findings offer an explanation as to why an MSA is not always successful particularly in ears in which the malleus lies very anteriorly thus unavoidably angulating the prosthesis. It also provides the explanation for the observation that a prosthesis placed between the stapes head and the tympanic membrane (providing direct transmission from the tympanic membrane to the stapes footplate) often produces better results.

Disappointment with the results using columellae is due largely to their lack of adherence to the stapes footplate leading to either inaccurate positioning at the time of operation, or subsequent movement during healing of the tympanic membrane. This has led to the introduction of numerous synthetic alternatives to natural materials. The results, in terms of air-bone gap closure (<11 dB), at one and five years for cartilage columellae and TORP are illustrated in Figure 1. These reconstructions were in stable ears following treatment of cholesteatoma in the above department by one of the authors (GDLS), using open and closed techniques. The

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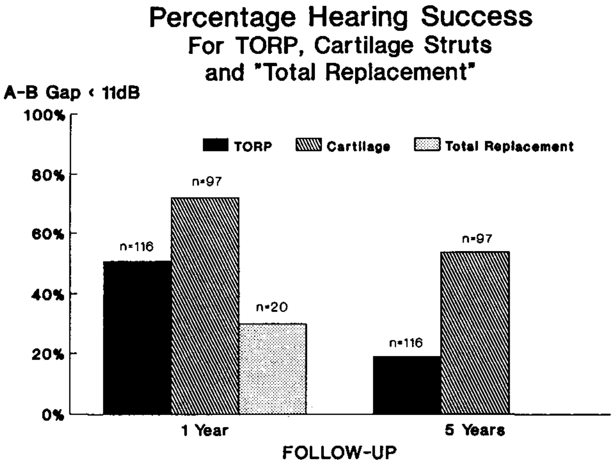

FIG. 1

hearing benefit obtained with the plastic prosthesis was inferior to that obtained with the cartilage at one year, and had deteriorated still further at five years. The results of an evaluation of the porous polyethylene prosthesis designed by the Treace Medical Company and called 'Total Replacement' again in stable ears is also summarized in Figure 1. This indicated an even poorer performance when compared to the cartilage columellae, and it was thus considered that the five-year results would not add to the clinical evaluation and this prosthesis is no longer used in this clinic. A similar clinical study was performed using a ceravital prosthesis, and the outcome in terms of air-bone gap closure (<20 dB) is shown with the results reported by Reck and Helms (1985) in Figure 2. The results of the two ceravital series are similar, however when compared to the <10 dB results of Smyth (22 per cent at 1 year and 20 per cent at 5 years) are inferior to those obtained using cartilage columellae (Fig. 1).

The dangers of too early evaluation of hearing results in terms of air-bone gap closure can not be over emphasized. The pattern of continued hearing loss over time, irrespective of the type of reconstruction employed, is illustrated by study of a group of our patients treated by a staged Palva procedure. The deterioration in hearing common to all types of reconstruction is shown in Figure 3, where the results of cases with an intact chain, myringostapedopexy, MSA, and TORP are illustrated. This pattern of progressive deterioration was also seen in patients whose chronic otitis was treated with a staged intact canal wall technique or a modified radical mastoidectomy. So it would appear that one of the realities of ossiculoplasty is that even if the patient is fortunate enough to have a good result in terms of air bone gap closure initially, deterioration with the passage of time is very likely. Another important consideration in the reporting of results of ossiculoplasty is the fate of those patients who are inevitably lost to follow-up. The method of dealing with these patients can have a significant effect on the overall results. The indirect actuarial life table method is a means of ensuring that the results from all patients contribute even if they are not observed for the follow-up, and should be employed in the reporting of results (Austin, 1989).

What does the patient want?

Most reports on the success or failure of reconstruction of the ossicular chain employ air bone gap closure as the main method of measurement. This parameter is useful when comparing the performance of one material or technique with another, but it may be inappropriate from the point of view of the patient. The request from the patient with a hearing loss is never—can you close my air bone gap? This method of evaluation also suffers from the fact that the transmissional element of bone conduction measurement by standard methods will be enhanced by an efficient reconstructed ossicular mechanism, and therefore bone conduction thresholds may be improved post-operatively (Smyth and Hassard, 1981). Alternatively bone conduction thresholds may have deteriorated due to intra-operative trauma; after all, to reduce the argument to the point of absurdity the most effective way of closing the air bone gap is to produce a dead ear! As will be proposed below it is more useful to plot the air conduction changes which are achieved by various reconstructive techniques. This measure provides a more realistic indication of the prospects of improving the patient's overall auditory performance because the aim of ossiculoplasty is not to close the air bone gap but to reduce the patient's auditory disability. In general the degree of disability is determined by the status of the better ear. The ideal of bilateral normal hearing is often unattainable, and so in advising patients regarding surgery for hearing gain it is

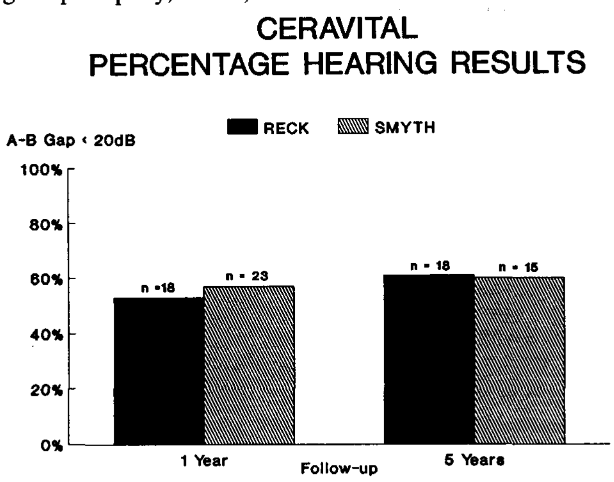

FIG. 2

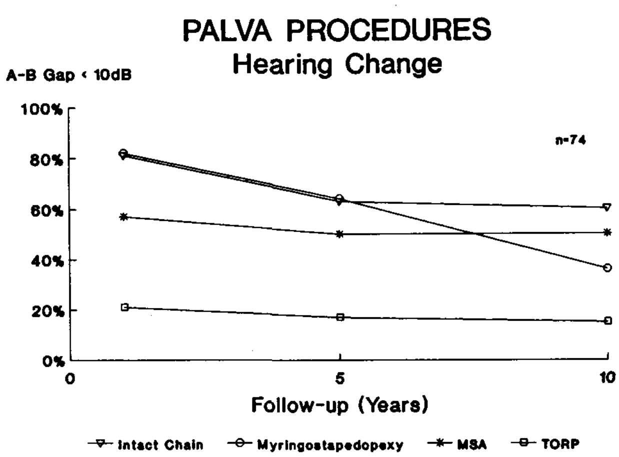

FIG. 3

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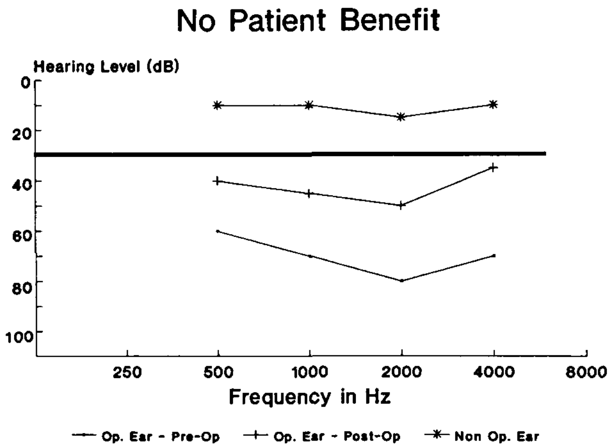

FIG. 4

important not to forget the contribution of the other ear. Hearing is a bilateral sense and the central auditory pathways receive input from both cochleas. Unless the contribution of the operated ear to the activity in the central auditory centres is increased post-operatively, the surgery will be of limited benefit to the patient. In most cases the worse hearing ear will be selected for reconstructive surgery, but unless the proposed surgery can restore symmetrical or nearly symmetrical hearing, or convert the operated ear into the better ear, the patient is unlikely to experience a reduction in disability.

The requirements for patient benefit were assessed by Smyth and Patterson (1985). They concluded that for significant benefit to be achieved the postoperative air conduction (AC) average over the speech frequencies (0.5, 1, 2 and 4 KHz) must be <30 dB or the interaural difference reduced to <15 dB. This figure of 15 dB corresponds to the cross-attenuation effect of the skull (Browning, 1986).

Figures 4 and 5 illustrate the importance of evaluating the contribution of the contralateral ear. In the case shown in Figure 4, despite the improvement in air conduction threshold, the interaural difference remains >15 dB and the AC average >30 dB; the patient is unlikely therefore to be aware of the audiometric improvement. In the second case, Figure 5, although the change in AC is the same, because the post-operative AC average is within 15 dB of the other ear the patient will obtain a significant improvement in auditory function. The Glasgow plot devised by Browning *et al.* (1991) is a valuable elaboration of a bivariance distribution published by one of the authors (Smyth *et al.* 1980) to illustrate hearing status of otosclerosis patients operated on one ear only.

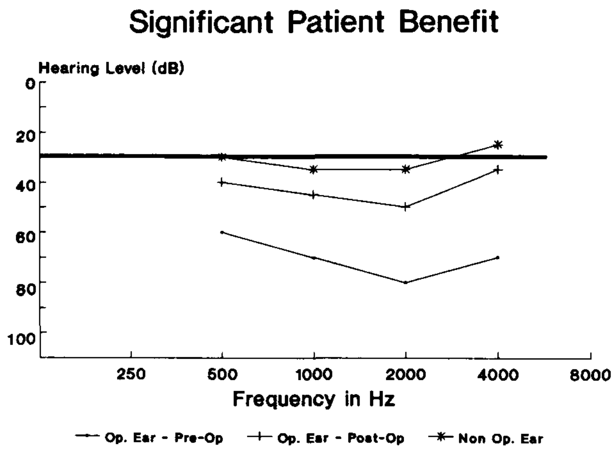

FIG. 5

By adding a horizontal and vertical axis at 30 dB, three different categories of pre-operative auditory status can be identified. (1) unilateral hearing loss; (2) asymmetrical bilateral hearing loss and (3) symmetric bilateral hearing loss (Figure 6). Post-operatively the patient's hearing status will move vertically downward on the graph (assuming no iatrogenic loss). If the patient with a unilateral hearing loss can be given symmetrical hearing post-operatively (area 1 to area 'a' Figure 6) then the reduction in auditory disability will obviously be significant. The patient benefit attained from moving the operated ear in a patient with bilateral hearing loss into the normal range (area 2 to area 'b') will also be significant. However for the patient who post-operatively still has a bilateral hearing loss (ie areas 2 or 3 to areas 'c' or 'd'), the benefit will be marginal and limited to poor listening situations.

If, therefore, the surgeon is aware of his success rates for the various pre-operative categories, he will be able to advise the patient realistically as to the potential benefit of the surgery.

Materials and methods

Employing this device we made a retrospective study of 100 patients who had open mastoidectomy and 100 who had staged combined approach tympanoplasty. All these patients had surgery for cholesteatoma and the majority have been followed up for almost 10 years. The aims of this retrospective study have been firstly to illustrate how successful past attempts to improve hearing have been, and secondly to provide air conduction averages for each type of reconstruction. This information would be useful in conjunction with the Glasgow plot (or similar system) as a prognostic device to predict patient benefit pre-operatively.

Results

The analysis of the air conduction changes (Fig. 7 intact chain cases and Fig. 8 MSA cases) produces information which is disappointing particularly when the

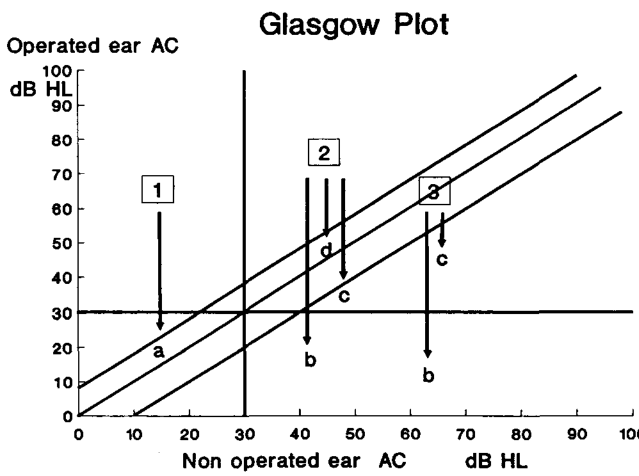

FIG. 6

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AIR CONDUCTION CHANGE INTACT CHAIN

	SUCCESS Average Gain	FAILURE Average Loss	TOTAL AVERAGE CHANGE
C.A.T.	9dB (n=22)	- 15dB (n=2)	+ 7dB
Open Cavity	4.5dB (n=20)	- 19dB (n=7)	- 1.7dB

C.A.T = Combined approach tympanoplasty

FIG. 7

average for all the patients is taken. The small numbers in each category even from this relatively large series highlights the problem in collecting sufficient data due to the scatter of reconstructive techniques. Excluding the patients where the hearing is worse postoperatively (where presumably there was a technical error), the results are more encouraging. However poor outcomes are unlikely to be avoided by prediction in advance. As will be seen from Figure 9 many patients have failed to benefit in terms of their overall auditory status. These patients were probably given an unduly optimistic prognosis because of the failure to take account of the other ear.

Conclusions

The realities of ossiculoplasty whic h should always be borne in mind (to temper the natural optimism of most surgeons) when advising patients as to the likely benefit of surgery may be summarized as follows:

1. It is important that the 'Glasgow plot' system or alternatively the criteria for patient benefit advocated by Smyth and Patterson (ie the operated ear to better than <30 dB or within 15 dB of the other ear) are used. If not many patients will be advised to have operations which they are likely to regard as unsuccessful in reducing their auditory disability.
2. There are now clearly defined patient categories which are probably unsuitable for purely functional surgery. These include tympanosclerosis involving the oval window region (Smyth and Gormley, 1987) and ears with loss of stapes superstructure. Patients in these categories are more likely to benefit from the provision of a hearing aid, though some may require a myringoplasty to stabilize the ear prior to fitting an aid.

AIR CONDUCTION CHANGE M.S.A. RECONSTRUCTION

	SUCCESS Average Gain	FAILURE Average Loss	TOTAL AVERAGE CHANGE
C.A.T.	19dB (n=11)	- 10dB (n=2)	+14.5dB
Open Cavity	12dB (n=9)	- 23dB (n=5)	-0.7dB

M.S.A = Myringostapedopexy

FIG. 8

OVERALL PATIENT BENEFIT "GLASGOW PLOT" SYSTEM

	C.A.T.(2 Stages)		OPEN CAVITY	
PATIENT BENEFIT	M.S.A n=10	Long Columella n=12	Short Columella n=13	Long Columella n=10
Significant	70%	0%	38%	30%
Marginal	0%	17%	8%	0%
No Benefit	30%	83%	54%	70%

Long Columella = cartilage strut between stapes footplate and tympanic membrane

Short Columella = ossicular strut between stapes footplate and tympanic membrane

FIG. 9

3. Surgeons who are unaware of their own success rates in terms of closure of the air-bone gap and air conduction change will be liable to advise their patients inaccurately regarding the outcome of surgery for a purely functional result.
4. Analysis of the results of ossicular reconstruction in CSOM if carried on for an adequate period (at least 15 years), will reveal a progressive deterioration.
5. The problems associated with reconstructing ears involved by chronic otitis media are quite different from, and much more difficult to overcome than those in patients suffering from otosclerosis. The chronically infected ear has usually several deficits involving the tympanic membrane, the mucosal transport and middle ear ventilation systems, the ossicular chain, and cochlear function in varying proportions, whereas the otosclerotic ear has only one abnormality of the conductive system.
6. Although the physiology of middle ear function if well understood, the physics of the reconstructed ear are not—the most relevant recent work is that of Vlaming and Feenstra (1986).
7. Normal hearing requires the distribution of information from both cochleas to both auditory cortices, hence advantages of binaural as opposed to monaural hearing. Only if an operation can restore more effective auditory function will the result be of benefit to the patient.
8. Average air conduction gains of all categories of middle ear reconstruction are comparatively small and tend to be less if the stapes superstructure is lost.
9. In ears without a stapes superstructure columellar reconstructions with cartilage have proved to be best in our hands. Reconstructions with two types of porous polyethylene and ceramic have been significantly less successful.

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